LII. The After-Effect of Seen Movement When the Whole Visual Field is Filled by a Moving Stimulus

By Wellington A. Thalman

In his study of the after-effect of seen movement A. Wohlgemuth reports a series of 34 experiments whose results he uses to disprove current theories and to support his own theoretical construction.[1] One of these experiments, the 22d, is devised "to ascertain how the after-effect is affected if the whole visual field is filled by an objective movement." The outcome is negative: there is "a total absence of any after-effect." Wohlgemuth, apparently dissatisfied with this finding, repeats the experiment, with identical result. He accordingly concludes that "no after-effect is produced by an objective movement occupying the whole visual field."[2] Later, in his theoretical sections, he reviews and rejects all current theories "either for *a priori* reasons or on account of incompatibility with experimental evidence," and proceeds, on the basis of McDougall's theory of drainage, to the construction of a theory which shall be "in harmony with the ascertained facts."[3] But in relating this theory to the facts *he fails to consider the results of his own Experiment 22.*[4] Yet these results, if they stand, appear to contradict the theory, according to which the phenomenon is in no way conditioned upon size or spread of the stimulus but is wholly dependent on priority of entry and the consequent decrease of synaptic resistance. If the after-effect fails to appear when the whole field is stimulated, the theory must either be discarded or radically revised.

We hold no brief for the theory; but we were not either convinced by the outcome of the critical experiment, which we therefore decided to repeat. We hoped also, by extending the method, by requiring introspective reports of process as well as statements of meaning, and by improving the apparatus and technique, to contribute something toward a complete phenomenology of the illusion.

Observers.—We had two groups of *O*'s. The members of the first group were Mr. W. A. Andrews (A), and Mr. S. Takaki (T), graduate students in psychology; Mrs. I. G. Whitchurch (W), graduate scholar in psychology; Dr. F. L. Dimmick (Di), assistant in psychology; and Dr. K. M. Dallenbach (Da), instructor in psychology. We gave these *O*'s a preliminary practice-series that should bring them

[1] *Brit. Journ. Psych.*, Mon. Suppl. 1, 1911, 1-117.

[2] *Op. cit.*, 72, 113.

[3] *Op. cit.*, 98 f. For McDougall's drainage-theory see *Brain*, xxvi, 1903, 153 ff.

[4] The experiment is referred to by number on p. 106; but the "Experiments 20-22" there mentioned should undoubtedly be "20, 21," since we read immediately after of "these two [not three] cases," and since the separate discussion on p. 109 mentions only Exps. 20 and 21. The slip on p. 106 is unfortunate, as it led the author to leave Exp. 22 out of account.

to the pitch of proficiency that Wohlgemuth's *O*'s had attained.[5] They were required to report on both process and meaning. The members of the second group, whom we shall quote only by number, were with two exceptions students in the summer session of 1920. These *O*'s approached the problem without special training, and were asked to report only upon meaning.

Preliminary Practice.—We used in the preliminary work a demonstrational model of James' artificial waterfall,[6] with and without a fixation point, in both the vertical and the horizontal positions. The curtain was rotated by hand at two speeds, fast and slow, and the rotation was continued for 5, 10, 15, 20 or 25 sec. There were thus 40 possible experiments; and as every experiment was repeated 5 times, every *O* gave 200 reports upon the illusion. Observation was binocular, at a distance of 25 cm. An adjustable biting-board served to steady *O*'s head and aided him to maintain his fixation.

The results of this practice-series may be summed up as follows. (1) All *O*'s obtained the illusion of backward movement. (2) The after-effect became more pronounced as practice advanced. (3) The after-effect became more pronounced as the exposure grew longer and the rate of rotation faster. (4) The presence or absence of a fixation point made no difference in the illusion. (5) The after-effect was as marked with horizontal as with vertical movement of the stimulus.

Repetition of Wohlgemuth's Observations.—We next set up Wohlgemuth's apparatus and repeated his observations. The apparatus,[7] which consisted of an endless band of printed calico of alternating black and white stripes 5 mm. wide, 180 cm. broad and 110 cm. high, stretched between two rollers, was placed in a dark room and was so illuminated by daylight mazda lamps that no shadows fell upon its surface. The band was driven by an electric motor which, by means of a multiple speed-reducer, moved it downward at a velocity of 12 cm. per sec.[8] The times of stimulation were 30, 45 and 60 sec.[9]

No one of our *O*'s found the entire field of vision filled by the black and white surface, even though he stood so close that his nose actually touched the cloth. Always there was an unfilled margin. It may be that Wohlgemuth's *O*'s failed to report this fact; it may be that Wohlgemuth regarded it as of no consequence. Since, in his second attack upon the problem, he reduced the dimensions of the stimulus-field to a square of 80 cm. side,[10] it is probable that he aimed

[5] On the importance of practice see Wohlgemuth, *op. cit.*, 27, 110.

[6] W. James, *Mind*, O. S. xii, 1887, 517; *Principles of Psych.*, ii, 1890, 245.

[7] *Op. cit.*, 72.

[8] Wohlgemuth does not state his rate of movement. We chose that of 12 cm. per sec. because his experiments on the "influence of the velocity of the stimulating movement upon the after-effect" (Exps. 10-13, pp. 45-52) showed that the optimal rate lay between 6 and 12 cm. per sec. (see Fig. 8, p. 50). These experiments were performed with central vision. Our own experiment involves peripheral vision, and we therefore thought it best to take the upper limit.

[9] We used these long times, although the preliminary practice-series had proved them unnecessary, in order to conform with Wohlgemuth's procedure; see *op. cit.*, 72.

[10] *Ibid.*

only at a relative filling of the field of vision. Wohlgemuth, again, used a fixation point throughout his observations.[11] It is clear that this point, with the wire that held it in place, further violates the conditions of complete objective movement. Our practice experiments had shown that the fixation point is unnecessary, and we therefore discarded it in part of our own work.

We performed three series of experiments with this apparatus. In the first we sought exactly to duplicate his conditions, and therefore introduced a fixation point. A piece of wire carrying a small white square of 5 mm. side was let down from above and ended at the center of the field, about 1 cm. in front of the cloth. In the second and third series the fixation point was removed. In the second, the *O*'s were directed to fixate the surface of the moving field; in the third, they were directed to look through and beyond the cloth, to fixate at 'infinity.'

The following instructions were read to the *O*'s at the beginning of every observation-hour: "Take a position about 10 cm. in front of the center of the screen. When you have done this, close your eyes and wait until the experimenter says 'Ready,' 'Now.' On the 'Now' open your eyes and (*a*) keep your eyes steadily upon the fixation-point; (*b*) fixate the surface of the moving field; (*c*) look through and beyond the screen and fixate at 'infinity.' When the objective movement has ceased and the resulting phenomena have run their course, give a complete account of them."

While the *O*'s had their eyes closed the motor was started, and the screen was allowed to reach its full velocity before the 'Now' was given. At the end of the experiment the screen was instantly stopped; and when the after-effects, if any, had run their course, the *O*'s turned to the description.

Every experiment was repeated twice with every exposure time. The number of times, expressed in percentages, that an after-effect was reported, is shown in Table I.

TABLE I

SHOWING THE PER CENT. OF CASES IN WHICH THE AFTER-EFFECT WAS REPORTED WHEN WOHLGEMUTH'S APPARATUS WAS USED

	Observed		
		Without Fixation-Point	
O	With Fixation-Point	Near Fixation	Far Fixation
A	33%	100%	66%
Da	16%	100%	33%
Di	0%	100%	100%
T	66%	100%	100%
W	100%	100%	100%
1	50%	100%	100%
2	50%	33%	100%
3	66%	66%	66%
4	16%	0%	0%
5	0%	0%	0%
6	0%	0%	66%
Average	36.3%	63.6%	66.6%

[11] *Ibid.*

The after-effect was variously reported as a "slow upward movement," a "rapid upward movement," a "reverse movement," a "rebound," a "jerk upward," a "recoil," a "spring up." The direction of movement in the after-image was always opposite to that of the objective stimulus. The rate, extent, and duration of the movement varied considerably: it was described as rapid, as medium, and as slow; it was local (around the fixation point), general (extending over the entire field), or intermediate between these extremes; it passed through a small angle and was reported as "upward about an inch," or through a large angle and was reported as "upward a foot," or it was intermediate; and it was of short, intermediate or long duration.

The apparatus as employed by Wohlgemuth, with a fixation-point, afforded on the whole the least favorable method for observation of the phenomenon. But even under these unfavorable conditions the *O*'s, on the average, reported its presence in more than one-third of the experiments. The individual differences between *O*'s was large. Of the trained *O*'s, W reported the after-effect in every experiment, wheras Di failed to observe it in a single case; of the untrained *O*'s, 1, 2, and 3 reported an after-effect in at least half of the experiments, whereas 4, 5 and 6 reported it in few or none.

The after-effect was noted in a larger percentage of the cases when the fixation-point was removed. The figures given in Table I show that an after-effect was, on the average, reported by all the *O*'s in about two-thirds of the cases.

There is very little difference in the results with near and with far fixation: an after-effect was reported in 63.6% of the experiments with near, and in 66.6% of those with far fixation. In these experiments the individual differences among the trained *O*'s was very small: with near fixation every *O* reported the phenomenon after every experiment; with far fixation Di, T, and W continued to report the after-effect after every experiment, whereas A and Da failed to observe it in ⅓ and ⅔ of the experiments respectively. The untrained *O*'s show greater individual variation. Some gave descriptions which compare with those of the trained *O*'s, while others, like Wohlgemuth's *O*'s, failed to observe an after-effect.

The effect of practice and training is clearly marked. Those *O*'s who had taken the practice series reported the after-effect more frequently and more consistently than the untrained *O*'s. Two of the untrained *O*'s, 1 and 2, gave reports and percentages which resemble those of the practised group. These *O*'s were both psychologists, and their general training in observation sufficed to differentiate them from the unpractised and untrained group.

In a number of the experiments in which no after-effect was observed the *O*'s stated that the objective stimuli fused as in color-mixing; the white and black lines disappeared, and the background became a uniform grey. Fusion was more frequently reported with fixation, when the eyes were strained and attention was concentrated upon the white square, than without.

We conclude from our repetition of Wohlgemuth's experiments (1) that the apparatus is unsuited to the problem. For (*a*) the entire visual field is not covered by an objectively moving stimulus; (*b*) in order to approximate this condition the *O*'s must stand so near the moving field that the black and white tend to fuse; (*c*) fusion is especially noticeable in experiments in which a fixation point, with

the resulting strain of convergence and concentration of attention, is introduced; and (*d*) the presence of this point and of its wire support violate the conditions of complete objective movement; the point of clearest vision and maximal attention is stationary. We find (2) that even under the unfavorable conditions of Wohlgemuth's procedure the after-effect may be observed. The reports vary considerably, but correlate roughly with the training and experience of the *O*'s. Trained *O*'s and experienced *O*'s without special training report a reverse movement in about half of the experiments. We note (3) that if the problem of the after-effect of complete visual movement is to be successfully attacked we must change the apparatus: (*a*) the whole field of vision must be stimulated; (*b*) the fixation point must be eliminated; and (*c*) the distance of *O* from the moving field must be large enough to rule out eye-strain.

Principal Experiment.—The apparatus which we finally constructed consisted of a large cylinder 1.7 m. high and 1.25 m. in diameter.[12] On the inside we glued heavy white architect's paper on which had been drawn in carbon ink at intervals of 7 mm. black lines 7 mm. in width. The cylinder was supported from above by a shaft projecting from a ball-bearing swivel joint.[13] It was rotated by an electric motor at two rates of speed, which we shall hereafter designate as 'fast' and 'slow.' At the fast rate the cylinder moved with a velocity of nearly 60 cm. per sec., at the slow rate with a velocity of approximately 30 cm. per sec.[14] The times of stimulation were 5, 15 and 25 sec.[15] The apparatus was placed in a dark room, so that the illumination was under control. The cylinder was lighted from within by a daylight mazda lamp placed above and slightly in front of the *O*. There were no shadows, and the illumination was uniform over the whole field of vision.

The *O* sat upon a stool at the centre of the cylinder. A biting board, rigidly supported from the floor, was employed to insure a constant distance of 29 cm. between *O*'s eyes and the cylinder wall.

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[12] An apparatus of this form was used by J. Aitken in 1878 (*Proc. Royal Soc. Edin.*, x, 1878, 40 ff.; *Journ. Anat. Physiol.*, xiii, 1879, 322 ff.) with negative results. The cylinder was rotated about the *O* and then lifted; no after-effect was observed upon the surrounding objects. The sole uniform experience was a disagreeable, sickening effect. E. Budde employed the same apparatus in 1884 (*Arch. f. Anat. u. Physiol.*, 127 ff.). The experiences set up were so trying that the experiments were soon broken off.

[13] This is a part of the apparatus for localisation of sounds described by M. Bentley, this JOURNAL, xxiii., 1912, 509.

[14] The exact rates were respectively 57.3 and 34.1 cm. per sec. Cf. Wohlgemuth, *op. cit.*, 28, par. 8.

[15] We had found, in our preliminary experiments, that the short exposure times were as effective as the long to produce the after-image of movement. Nausea and dizziness, as the two earlier authors found (footnote 12), result from the stimulation of the cylinder; but they may be eliminated by shortening the time of exposure. With the intervals used, only two *O*'s reported these experiences; and in neither case were they sufficiently strong or unpleasant to force a withdrawal from the experiment. As the experiment progressed these *O*'s became habituated, and (like the other *O*'s) were unaffected even by the 25 sec. stimulation.

This distance, chosen after trial, proved very satisfactory; there was no noticeable eye-strain.

The cylinder was stopped by a brake operated from *E*'s desk by a rigid lever-arm 3 m. in length. The effect was absolute and instantaneous. Great care was taken with this part of the apparatus; and records by the graphic method showed that the arrest of motion was sharp and abrupt; there was no indication either of continued movement or of rebound when the brake was applied.

There was no fixation point. The *O*'s were directed in half of the experiments to fixate the surface of the cylinder and in half to look through and beyond the screen, *i.*, to fixate at 'infinity.'

We had, then, two velocities, a fast and a slow; three durations, 5, 15, and 25 sec.; and two fixations. We had also separate instructions for meaning and for process. The series were repeated 5 times.

The *meaning* instructions were as follows: "When the signal 'Ready' is given close your eyes. The cylinder will then be set in motion. When the proper velocity has been reached the signal 'Now' will be given. On the 'Now' open your eyes and (*a*) fixate the surface of the screen at a point directly in front of you; (*b*) look through and beyond the screen, fixate at 'infinity.'"

In the preliminary experiments you reported, among other things, an after-effect of various degrees of intensity, duration, and extent. You are now to characterize this perception as fully as you can. Designate the degree of movement in the after-image on the following scale:

0. no after-effect
1. after-effect poor
2. after-effect fair
3. after-effect good
4. after-effect very good
5. after-effect excellent

When the objective movement has ceased and the resulting phenomena have run their course, give an account of them."

In the instructions for process the same general *Aufgabe* regarding signals and fixation was laid down. The specific instructions for meaning were omitted, and the following sentences were added: "In the preliminary experiments you reported after-images of movement. In this experiment you are to concentrate upon description. When the objective movement has ceased and the resulting phenomena have run their course, describe the mental processes in strictly psychological terms."

Only the practised *O*'s observed in this part of the experiment. The order in which the series were presented was different for every *O*, as follows:

Series	Observer				
	A	Da	Di	T	W
Meaning, near fixation.....	3	h	2	1	4
		a			
		p			
Meaning, far fixation.....	4	h	3	2	1
		a			
Process, near fixation.....	1	z	4	3	2
		a			
Process, far fixation.....	2	r	1	4	3
		d			

Results.—The results of the experiments upon 'meaning' appear in Tables II and III.

TABLE II

SHOWING THE NUMBER OF CASES IN WHICH THE AFTER-EFFECT WAS REPORTED, DISTRIBUTED ACCORDING TO THE POSITION OF FIXATION, THE RATE OF THE OBJECTIVE MOVEMENT, AND THE DURATION OF THE STIMULATION

O	Fixation	Rate	Duration				Total Near or Far	Total Slow	Total Fast
			5	15	25	Total			
A	Near	S	2	3	4	9	13	20	7
		F	1	1	2	4			
	Far	S	3	4	4	11	14		
		F	1	1	1	3			
	Total		7	9	11	27			
Da	Near	S	5	5	5	15	28	28	27
		F	4	4	5	13			
	Far	S	3	5	5	13	27		
		F	4	5	5	14			
	Total		16	19	20	55			
Di	Near	S	1	1	4	6	12	9	7
		F	1	2	3	6			
	Far	S	0	1	2	3	4		
		F	0	0	1	1			
	Total		2	4	10	16			
T	Near	S	4	5	5	14	27	25	26
		F	3	5	5	13			
	Far	S	2	4	5	11	24		
		F	4	4	5	13			
	Total		13	18	20	51			

O	Fixation	Rate	Duration				Total Near or Far	Total Slow	Total Fast
			5	15	25	Total			
W	Near	S	5	5	5	15	30	30	30
		F	5	5	5	15			
	Far	S	5	5	5	15	30		
		F	5	5	5	15			
	Total		20	20	20	60			
Summary			58	70	81	209	110/99	112	97

Table II summarises the cases in which the after-effect was reported by the *O*'s according to the position of fixation, the velocity of the objective movement, and the duration of the stimulation.

Under our conditions a negative after-image of movement was perceived by all *O*'s. This result was corroborated by those of the unpractised group, which now comprised 12 *O*'s. A series of five experiments, with near fixation, fast velocity, and a 25 sec. exposure, was taken with every member of this group. The meaning instructions alone were used. Four *O*'s reported the perception of reverse movement in every experiment; three in 80%; one in 60%; three in 40%; and one in 20% of the experiments. It should be recalled that all investigators have found that the after-effect becomes more pronounced with practice, and that this group approached the problem without the slightest training.

The results obtained from the two groups of *O*'s in this part of the experiment indicate that an after-effect occurs when the whole visual field is filled by an objective moving stimulus. Compulsory conditions, however, were not obtained for every *O*.

In the practised group compulsory conditions were obtained for three *O*'s: W reported the after-effect in every experiment, no matter how (within our limits) the variables were arranged; T reported it in every case when the stimulation had been extended to 25 sec.; and Da in every case when the fixation was 'near' and the velocity 'slow;' also in every case, no matter where the fixation or what the velocity (within our limits), when the stimulus was extended to 25 sec.

Compulsory conditions were not obtained for A and Di. Their reports, however, indicate the approach of compulsion: an increase in time of stimulation is paralleled by an increase in reports of the after-effect. For the 5 sec. exposure these *O*'s report the after-effect in 7 and 2 cases respectively; for the 15 sec. exposure, in 9 and 4 cases; and for the 25 sec. exposure, in 11 and 10 cases. Had our variable conditions been slightly extended, or had the time of stimu-

lation alone been lengthened,[16] it is very probable that we should have obtained compulsory conditions for them also. Owing to the short duration of the summer session it was impossible to carry the experiment further.

The summary at the foot of Table II shows that long stimulation, near fixation, and slow movement are, within our limits, the most favorable conditions for the perception of the illusion. As in the data of A and Di, so also in the results of the other *O*'s, the after-effect is most frequently reported when the exposure is extended to 25 sec. The summary also shows that the after-effect is reported 110 times with near fixation, 99 times with far; 112 times with slow rotation of the cylinder, 97 times with fast. The differences here are slight, and probably of little significance, since they are primarily due to the results of a single *O:* to those of Di in the matter of position of fixation, and to those of A in that of rate of rotation. Our conclusion is that position of fixation and rate of objective movement are irrelevant moments, and that the conditioning factor is the duration of stimulation.

These conclusions are confirmed by the *O*'s estimate of the cognitive clearness of the after-effect, which is presented in Table III.

These results parallel those of Table II. The *O*'s who report comparatively few cases of an after-effect place them for the most part at the lower end of the scale, whereas those who report many cases distribute them toward the upper end.

The results regarding the variable moments were likewise confirmed: the distribution upon the clearness scale for 'near' and 'far' fixation, and for 'slow' and 'fast' objective movement, shows no relevant differences, whereas the distribution according to the duration of stimulation shows a shift from the lower end for the short exposures to the high end for the long exposures. Even in the case of W, who reported the phenomenon in every experiment, the clearness of the after-movement shifts with the longest exposures to the highest degrees.

An analysis of the introspective reports yields the following results:

(1) The movement, given in the exposure and in the after-effect, is at times subjectified. Some *O*'s report that they revolved as on a swivel chair, and that the screen was stationary. The after-effect in these cases is merely a reversal, as in the rotary chair experiment, of the direction of the subjective movement. Examples are: (A) "Swimming sensations; I revolved in direction opposite to that of the cylinder. When the objective movement stopped, I rotated in the opposite direction;" (Di) "Pressures in head; feel of moving backward; this feeling kinaesthetic not visual;" (W) "Seemed as if I were doing the moving; felt as if I were moving to the right" (rotation of cylinder was to left).

[16] Wohlgemuth found that short stimulations of 5 sec. or less (Exp. 31, p. 85) failed to produce an after-effect of movement. He used exposure times varying from 20 sec. to 3 min. The majority of his experiments were performed with times lying between 30 and 60 sec. Our preliminary experiments showed that it was possible to obtain the illusion with the shorter times. The obvious advantage of using these shorter exposures lies in the fact, mentioned above, that the disagreeable and distracting effects, nausea and dizziness, caused by the rotating cylinder, were reduced to a minimum.

TABLE III

SHOWING THE NUMBER OF CASES IN WHICH THE AFTER-EFFECT WAS REPORTED AT THE VARIOUS LEVELS OF COGNITIVE CLEARNESS, AND A DISTRIBUTION OF THE CASES ACCORDING TO THE POSITION OF FIXATION, THE RATE OF MOVEMENT AND THE DURATION OF THE STIMULATION

O	Degree	Total No. Cases	Fixation		Rate		Duration		
			Near	Far	S	F	5	10	15
A	0	33	17	16	10	23	13	11	9
	1	10	5	5	8	2	3	4	3
	2	8	3	5	7	1	2	3	3
	3	5	3	2	4	1	2	1	2
	4	3	2	1	1	2	0	1	2
	5	1	0	1	0	1	0	0	1
Da	0	5	2	3	2	3	4	1	0
	1	23	15	9	13	11	11	7	6
	2	11	4	7	3	8	3	3	5
	3	12	5	7	8	4	1	8	3
	4	6	3	3	3	3	1	1	4
	5	2	1	1	1	1	0	0	2
Di	0	44	18	26	21	23	18	16	10
	1	13	9	4	9	4	2	2	9
	2	0	0	0	0	0	0	0	0
	3	2	2	0	0	2	0	1	1
	4	1	1	0	0	1	0	1	0
	5	0	0	0	0	0	0	0	0
T	0	9	3	6	5	4	7	2	0
	1	29	13	16	19	10	9	11	9
	2	19	13	6	6	13	3	7	9
	3	3	1	2	0	3	1	0	2
	4	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0	0	0
	1	3	2	1	2	1	3	0	0
	2	11	7	4	8	3	7	3	1
	3	3	1	2	3	0	1	1	1
	4	18	9	9	9	9	8	8	2
	5	25	11	14	8	17	1	8	16

(2) The black lines are at times seen in perspective; they are objectified, and appear as rods set at various distances from the eyes. All the *O*'s report experiences of this kind. Examples are: (A) "The lines stood out in perspective. Three in a group; that is, three were equally near, then the next three were back, next three close, and so on;" (Da) "At times the lines were seen in perspective, like black rods arranged at various distances in front of the observer;" (Di) "Lines stood in perspective;" (T) "The projection-effect was very

conspicuous; every second line seemed to stand out;" (W) "Once during the experiment there was a projection of the lines." "Twice during this experiment I noticed a projection; lines stood out in model-effect on grey background."

(3) The lines at times lose their shape and outline. Patterns of varying degrees of complexity appear upon the ruled surface. Simple changes (the lines become fringed and nodulated) and complex changes (large diamond and zig-zag effects) are of about equally frequent occurrence. The appearance of the simple and complex patterns can be correlated roughly with the slow and fast velocities. Examples are: (A) "The lines during motion became small squares, with vertical and horizontal cross-lines. These patterns appeared first at the center of the field of vision, and radiated until the entire field was covered;" (Da) "During the objective movement the field became spotted; the lines lost their regular outline;" "lines became nodulated;" (T) "Grey fringe to the right edge of the lines;" (W) "Lines became ripply;" "lines interwoven into complex pattern."

(4) Color effects are produced by the colorless stimuli. The hues are brilliant and filmy. They flicker and fluctuate. Sometimes they change as in the 'flight of colors;' sometimes antagonistic colors alternate; sometimes two colors (always antagonistic) appear together. Thus: (A) "The lines during motion became brilliantly colored;" (Da) "Left edge of lines blue, right edge yellow;" "lines alternately tinged with yellow and blue;" (T) "During objective movement the lines became wavy. The left side was colored, quality changing from yellow to red, to blue, to green, etc. The wavy figures instable, rapidly changing form and color;" (W) "During motion the lines became tinged with blue."

(5) The lines fuse as in color-mixing into a uniform background, in which case there is no after-effect; or into a flickering background as when the rotation of the color-mixer is too slow, in which case the after-effect is either not observed or if observed is reported as of low degree. Thus: (A) "Lines blended; there was no after-effect;" (Da) "Lines were nodulated; seemed to be stationary blinking spots" (no after-effect of movement was reported); (Di) "Faded to a shimmering gray." Di frequently reported this phenomenon; (T) "Lines became thicker in width at some points and thinner at others. Positions of thinness and thickness not constant, continually changing;" (W) "Toward end the whole thing became a mottled grey" (the after-image of movement was reported as poor).

(6) As Aitken and Budde discovered, stimulation from within the cylinder produces a widespread organic and muscular response. Dizziness and nausea are frequently reported, and tend to obscure the process-configuration. Examples are: (A) "Swimming in head;" (Da) "Strain sensation in muscles of eyes and pressure within head. Dizziness and an organic stir-up;" (Di) "Intense pressure in head, eye strain, and slight dizziness;" (T) "Very strong strain in eye muscles and dull pressure in head;" (W) "Very dizzy and nauseated, pressure sensations in head."

The occurrence of the after-effect can be directly correlated with the arousal of these phenomena. Di, who reports the after-effect least often, reports dizziness but once; W, who reports the after-effect in every experiment, reports dizziness most frequently. This correla-

tion does not indicate, however, that 'dizziness' is essential to the appearance of the after-effect. No *O* reports dizziness every time that he reports the after-movement. It is only in the early experiments that the correlation, even with W, invariably occurs. It appears, therefore, that the optimal conditions for the after-effect are also optimal for the perception of dizziness. It is not until these perceptions became habituated that the process-configuration becomes clear.

(7) The after-effect is reported in precisely the same terms as in our previous experiments. The same perception, an after-image of movement opposite in direction to that of the stimulus, and differing only in extent, is obtained when the entire visual field is filled by an objective moving stimulus as when, with James' waterfall apparatus, the stimulus is limited to a small area of the retina.

(8) The introspections at first include kinaesthetic and organic complexes. As the experiments progress and the *O*'s become accustomed to the experiences, the inessential elements drop away, leaving a residue of pressure and visual sensations.

The pressure sensations within the head never entirely disappear. They are always present when the after-effect is reported.

The visual configuration reported by three of the *O*'s—A and Di, even in the experiments under process-instruction, do not get beyond statements of meaning—is a qualitative and temporal, and perhaps spatial, integration. Examples are: (Da) "Immediately after the objective movement ceased the field became momentarily a blur and grayish; then the vertical lines stood out distinctly again;" "The gray blur was of short duration. On the side of meaning movement rapid;" "When objective movement ceased, field seemed to be covered by a gray cloud; this lasted for a short time; then the vertical lines appeared, distinct in outline. On the side of meaning movement slow;" "When objective movement ceased there was a momentary gray blur, which was followed by distinct vision. On side of meaning a rebound;" (T) "When the objective movement stopped there was a grey; the lines became wider; and then they became distinct again;" "When the objective movement stopped I saw gray like a film;" "When the objective movement stopped the lines momentarily appeared clear in outline, then expanded to right. Over these lines were gray lines; these were indefinite and instable" (reported movement as of the 2nd degree); (W) "When movement ceased lines blurred into a gray;" "After objective movement ceased each line seemed to become broader; meaning, movement to right;" "When objective movement ceased a gray screen appeared; this seemed to move to right."

Summary

(1) We divided our *O*'s into two groups; the one group was given a practice series before the main experiments were undertaken, the other group approached the problem naïvely.

(2) Repetition of Wohlgemuth's work showed:

(*a*) that his apparatus is unsuited to the problem;

(*b*) that even under unfavorable conditions the after-effect is reported in a large percentage of cases by *O*'s of both groups. Individual differences are large, and the effect of practice and training is clearly evident;

(*c*) that the apparatus, if the problem of the after-effect of complete visual movement is to be successfully attacked, must be variously modified.

(3) Experiments with a large cylinder, constructed to meet the requirements of complete visual stimulation, showed:

(*a*) that the after-effect is observed when the whole visual field is filled by an objective moving stimulus;

(*b*) that position of fixation and rate of objective movement (within our limits) are irrelevant moments, and that the conditioning factor is the duration of stimulation;

(*c*) that the characteristic processes of the after-effect are pressure sensations within the head and a qualitative, temporal, and perhaps spatial integration of visual sensations.

(4) Wohlgemuth's failure to attempt a reconciliation of his theoretical views with the negative results of his Exp. 22 turns out to be of no consequence: not because the results of that experiment are unimportant, but because under strict conditions they are positive. As it happens, Wohlgemuth's two negatives amount to an affirmative.